Radiative b-decays with ATLAS

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Preliminary analysis of B_d ® K^{*0}(892) g

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❶ Motivation

❷ Generation, simulation, reconstruction

❸ Analysis, results, and comments

❹ Conclusion & perspective

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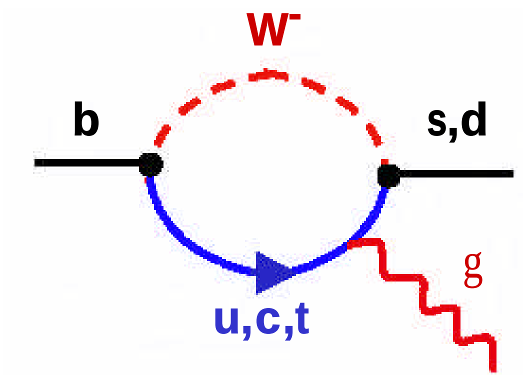
Physical interest

1. A laboratory for QCD



- New **constraints on CKM matrix** parameters (V_{ts}, V_{td}) could be obtained:

Form factors ratio

$$\frac{Br\,(\mathbf{B}\ \text{®}\ \mathrm{rg})}{Br\,(\mathbf{B}\ \text{®}\ \mathbf{K}^{*}\mathrm{g})} = \frac{|V_{td}|^2}{|V_{ts}|^2} \times R \times \Phi$$

Phase space factor

- **Branching ratios measurements** will give useful constraints on QCD parameters (form factors, m_b,...):

B quark mass

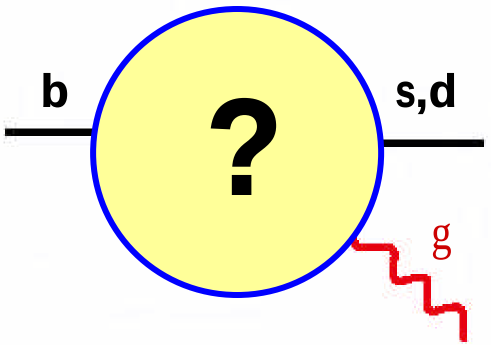
Form factor

$$Br\,(\mathbf{B}\ \text{®}\ \mathbf{K}^{*}\mathrm{g}) = (7.2 \pm 1.1) \times 10^{-5} \times \left(\frac{t_B}{1.6\mathrm{ps}}\right) \times \left(\frac{m_b}{4.65}\right)^2 \times \left(\frac{x_\perp(K^*)}{0.35}\right)^2$$

- **CP asymmetries** in B ® rg decays, **isospin violation** in B ® K*g & B ® rg decays.

Physical interest

2. New Physics influences



New diagrams appearing (**charged Higgs**, **chargino**, **squark** contributions)

↓

Physical observables (**branching ratios**, **CP asymmetries**) modified

↓

Modifications largely **model dependent** → **Useful constraints on new physics parameter space**

How to study B ® Xg with ATLAS?

❶ Inclusive measurements:

® Involve a very precise knowledge of the ‘non-B’ background (using, e.g., off-resonance data).
® Cannot be achieved (using classic methods) at LHC.

❷ Semi-inclusive measurements:

® An hadronic system with a single kaon and few pions is searched, then B meson is reconstructed. This method leads with a good accuracy to the photon spectrum.
® Quite difficult without an efficient K/p identification.

❸ Exclusive measurements:

® Direct reconstruction of principal decays (B ® K* g , B ® r g, ...).
® Certainly the more accessible to ATLAS

Event sample production

- **Generation: (Athena+PythiaBmodule+Model (*for signal*))**
  - 5.0.0 release, **(Pythia 6.2) :** 30k **B_d** ® **K^{*0}** g_4 events
    50k **$\bar{b}b$** ® m_6 **X** events
- **Simulation: (Atlsim)**
  - 6.0.2 release, **initial layout :** 16.5k **B_d** ® **K^{*0}** g_4 events
    50k **$\bar{b}b$** ® m_6 **X** events
- **Reconstruction: (Athena)**
  - 6.0.3 release, **initial layout :** 16.5k **B_d** ® **K^{*0}** g_4 events

Background coming soon...

Comparisons done with an old sample (2.4.1 reconstruction)

Strategy of the analysis

- **Level 1: *(Muon trigger)***
  - → m_6 **selection**: **a 85% efficiency is assumed** ***(muon reconstruction coming soon…)***
- **Level 2:**
  - → g **selection in the calorimeter:** g/p^0 **isolation, shower shape, p_t cut**
- **Offline cuts:**
  - → **K^{*0} reconstruction in the ID:** **Combination of pairs of "K^+p^-" tracks (*Vertex fit*), and K^{*0} invariant mass reconstruction. Cuts on tracks p_t, on impact parameter, Fit likelihood,…**
  - → **B_d invariant mass reconstruction:** **Cut on p_t, and invariant mass.**
- **Refined cuts:**
  - → **Cuts on angular distributions, g/K^{*0} center of mass momentum,...**

g selection

➡ **g cluster candidate is selected if :**

❶ *Cluster Et* **> 4 GeV**

❷ **0.5 strips** £ *cluster width* £ **3.5 strips**
❸ *Energy leakage in f direction* £ **9 %**
❹ *Energy leakage in h direction* £ **9 %**

➡ **Shower shape**

❺ *Energy proportion of strips* 2^{nd} *maximum* £ **6%**
❻ 2^{nd} *maximum physical meaning* £ **1.5%**

➡ **g/ p^0 rejection**

K^{*0} reconstruction

❶ K^+ selection :

- Positive charge
- $|\eta| < 2.5$
- $P_t > 1.3$ GeV

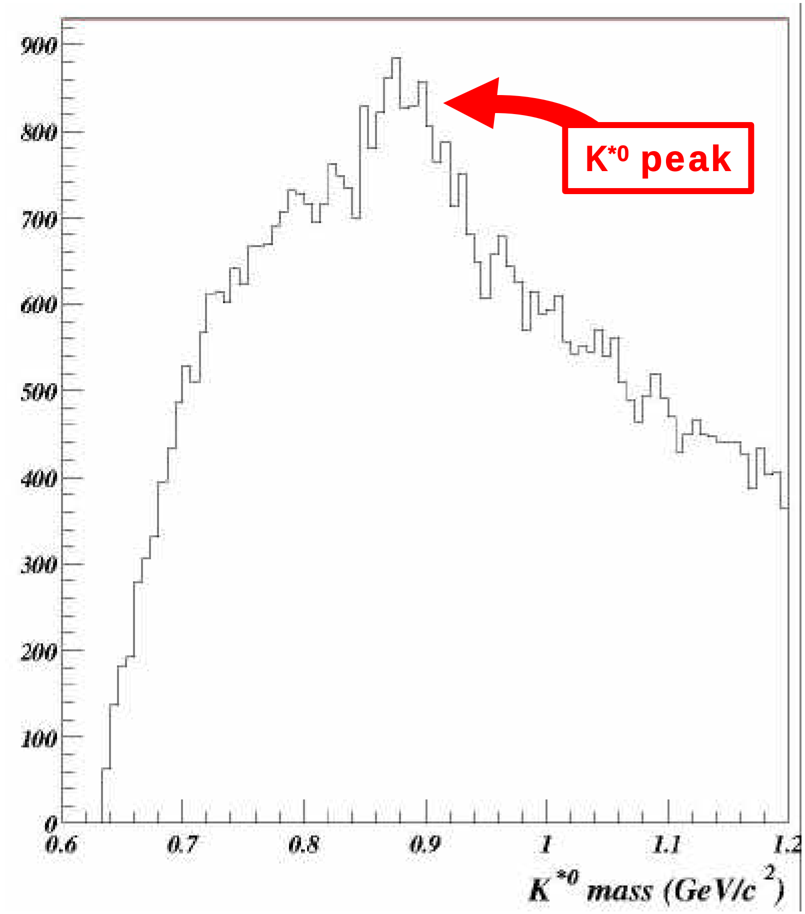
❷ π^- selection :

- Negative charge
- $|\eta| < 2.5$
- $P_t > 0.8$ GeV

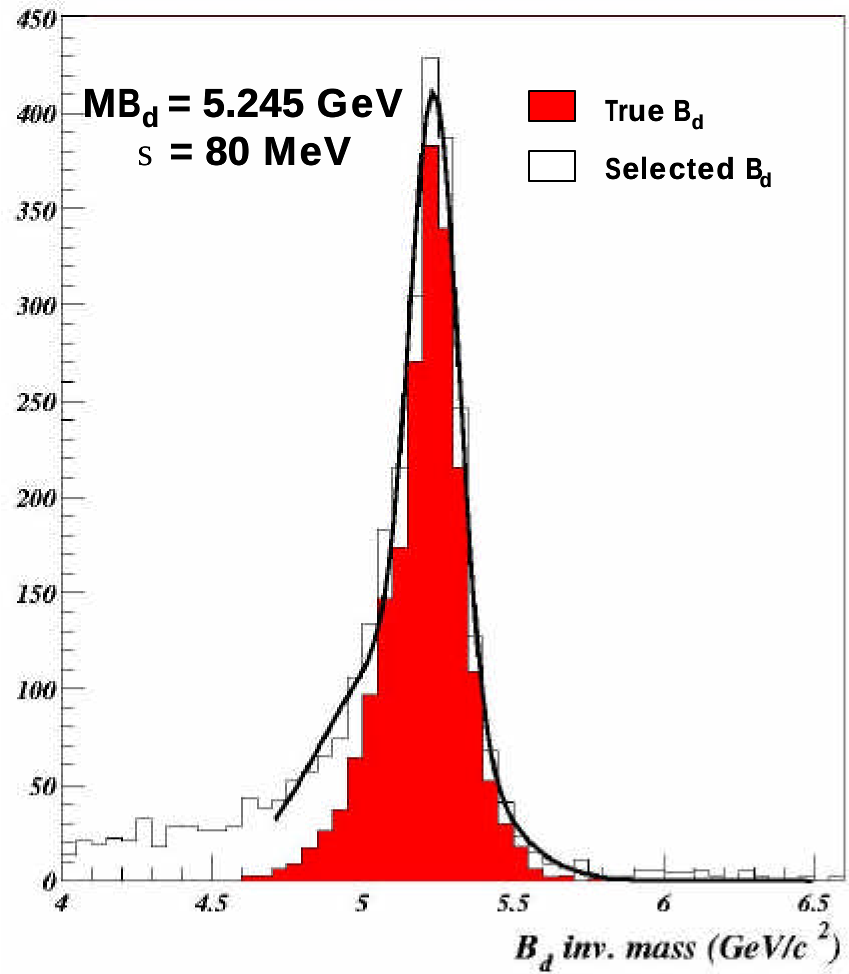
Vertexing of the 2 tracks.
K^{*0} selected if :

$\chi^2 < 6$ & $L_{tr}(K^{*0}) > 250\mu m$

2σ mass cut (σ = 90 MeV)



B_d final reconstruction
Signal only



- For each event, B_d candidate with best mass is selected.
- Reconstruction efficiency with off-cuts (in 3σ mass window) :

ε(True B_d) = 10%

- Signal purity (in 3σ mass window):

$$\frac{\text{True } B_d}{\text{Selected } B_d} = 60\%$$

Preliminary result

Refined offline cuts

❶ K^{*0} candidate is selected if :

0.2 GeV < $P^*_{K^+}$ **< 0.35 GeV**

0.2 GeV < $P^*_{\pi^-}$ **< 0.35 GeV**

P* = center of mass momentum

Impact(K^+)**x** Impact(π^-) **> 0**

Angle between K^{*0} p_t & B_d transverse length **< 40°**

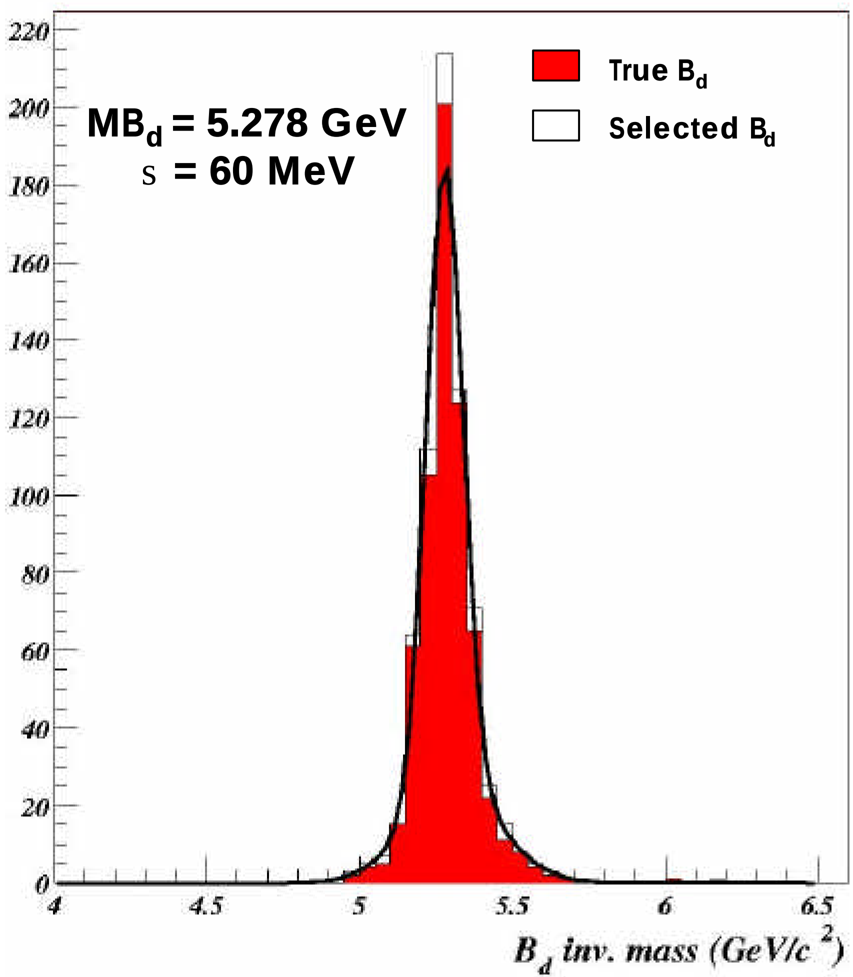
❷ B_d candidate is selected if :

1.8 GeV < P^*_{γ} **< 3.5 GeV**

1.8 GeV < $P^*_{K^{*0}}$ **< 3.5 GeV**

Minimal distance bet. γ trajectory & B_d decay vertex **< 9cm**

B_d final reconstruction
Signal only



- **Reconstruction efficiency with all the cuts:**

  ε(True B_d) = 3.85%

- **Signal purity (in 4σ mass window):**

$$\frac{\text{True } B_d}{\text{Selected } B_d} = 93\%$$

Preliminary result

Summary & conclusion

PRELIMINARY

	Offline	Improved
$\sigma(B_d)$	80 MeV	60 MeV
$\varepsilon_{reco}(B_d)$*	8.5%*	3.3%*
N(Signal)/y	143k**	55.5k**
N(Back)/y***	55×10^6***	*Not enough stat.*
Signal purity	60%	93%

$$\frac{S}{\sqrt{B}} \sim 19$$

* The L1 μ6 efficiency is included.

** L_{inst} = $2 \times 10^{33}\ cm^{-2}s^{-1}$

*** Old results with release **2.4.1** and **weaker cuts**.

Perspective

Just preliminary results ® still lot of work to do:

❶ Process the physics background with initial layout

❷ Perform cuts on K^{*0} angular distributions

❸ Vertexing routine *(Athena patch for displaced vertex, real magnetic field,...)*

❹ Look at Bd $\rightarrow \rho\gamma$ decay *(CKM matrix constraints)*

❺ Test the feasibility of a L1 calorimeter guided trigger **(g?)**

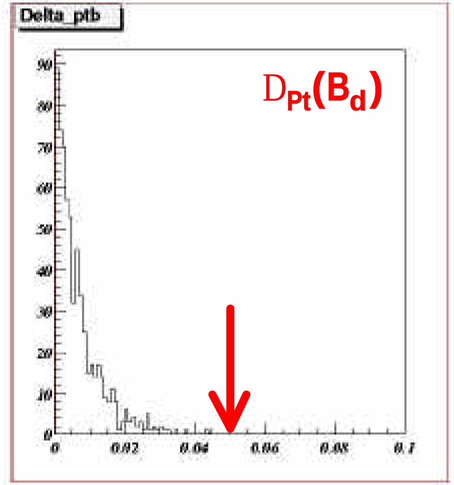
❻ High-luminosity feasibility

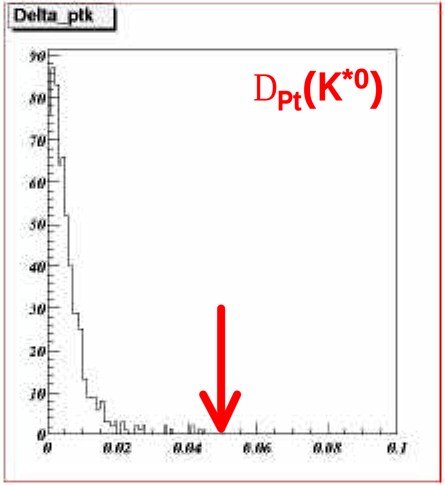
❼ ...

B_d authentication (*TRUTH*)

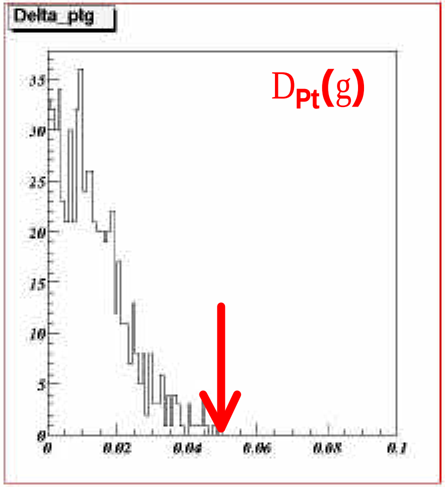
Is the reconstructed B_d true or fake ?

Calculated p_t's are compared to real p_t's (Using KINE)





$$\Delta_{Pt} = \frac{|p_t(\text{kine}) - p_t(\text{calculated})|}{p_t(\text{kine}) + p_t(\text{calculated})}$$



Reconstructed B_d is true if

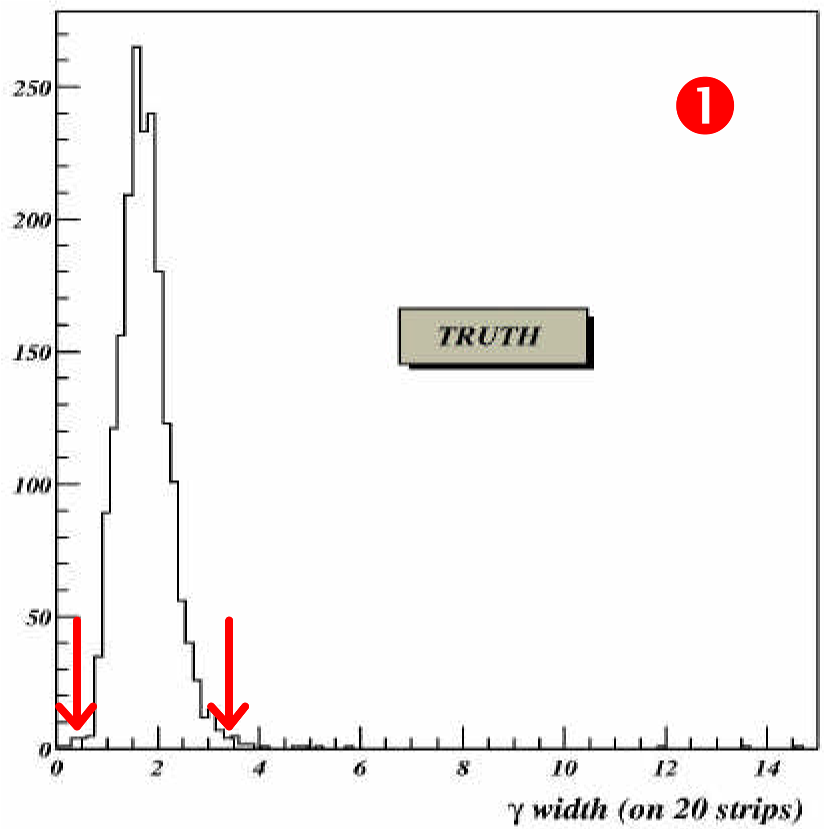
$$\begin{cases} D_{Pt}(B_d) < 5.0\% \\ D_{Pt}(K^{*0}) < 5.0\% \\ D_{Pt}(g) < 5.0\% \end{cases}$$

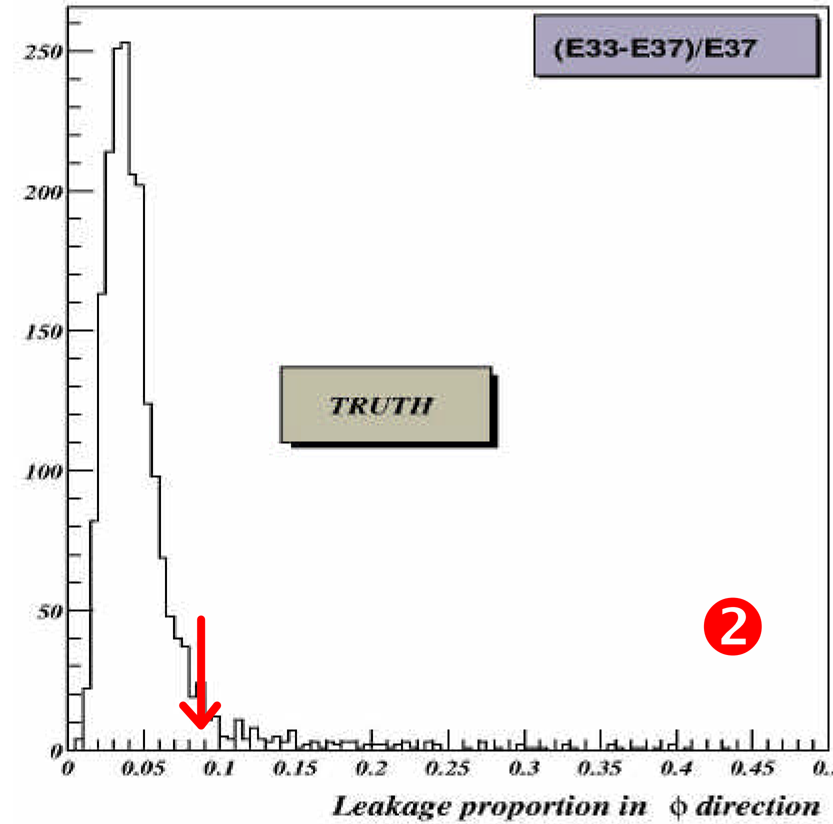
g selection

1. Shower shape

❶ **Total cluster width (over 20 strips)**

LVL2 cut: 0.5 strips £ *width* £ 3.5 strips



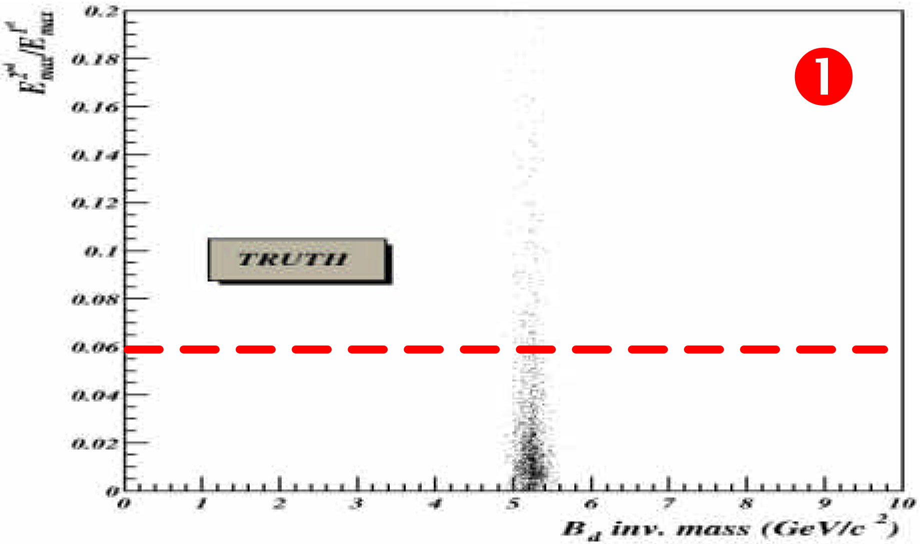


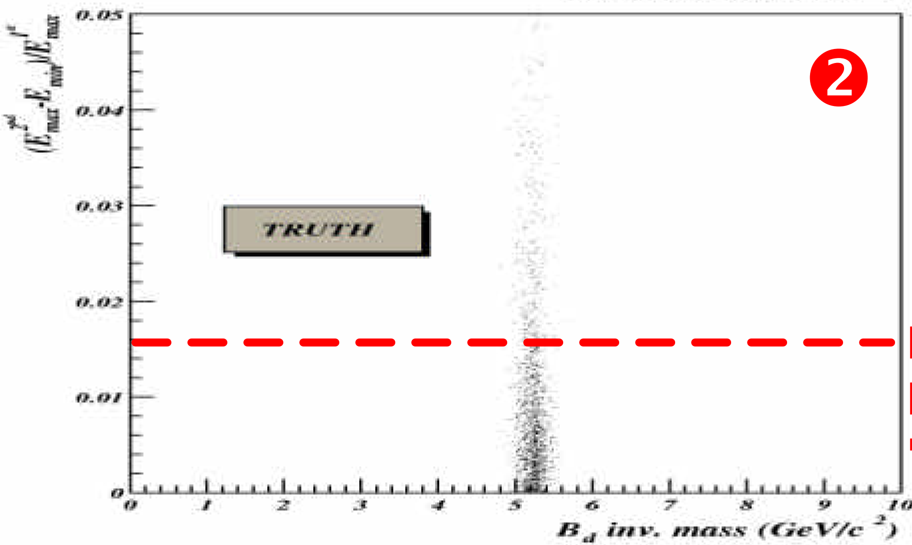
❷ **Shower shape in *f* & *h* direction (ECAL 2nd sampling)**

LVL2 cut: £ 9 %

g selection

2. γ/π^0 rejection





Search for a 2nd maximum in the strips:

- **g: no 2nd max**
- **p0: 2nd max close to the 1st one**

❶ Transverse energy of the 2nd max on total transverse energy in the strips

$$\frac{E^2_{max}}{E^1}$$

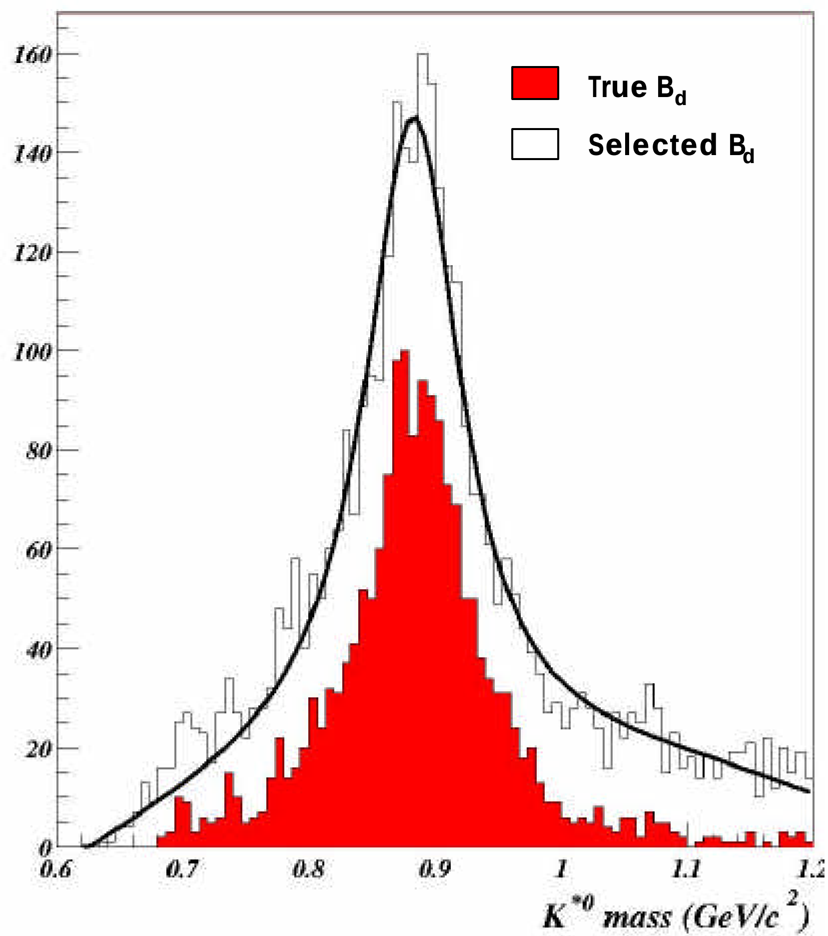
LVL2 cut: £ 6%

❷ Physical meaning of the 2nd max (real max or 1st max artefact). Look at the minimum energy between the two max and compare it to 2nd max energy

$$\frac{E^2_{max}-E_{min}}{E^1}$$

LVL2 cut: £ 1.5%

K^{*0} reconstruction
Mass window determination



A **raw** K^{*0} reconstruction is performed (no cuts)

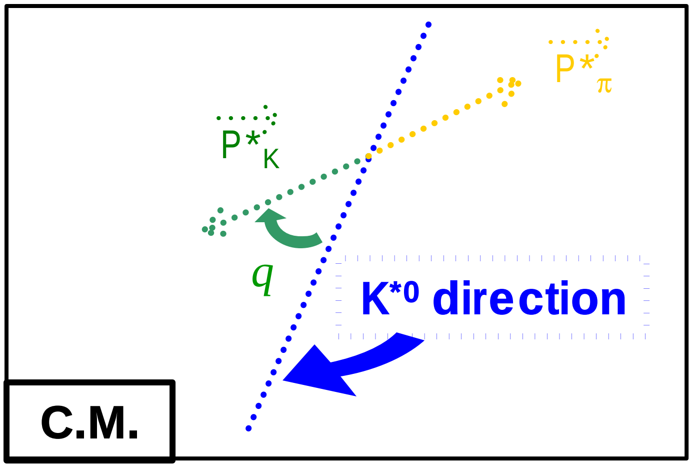
K^{*0} candidates giving a selected B_d are displayed

A **2σ mass window** cut on $M_{K^{*0}}$ is sufficient for correct signal reconstruction

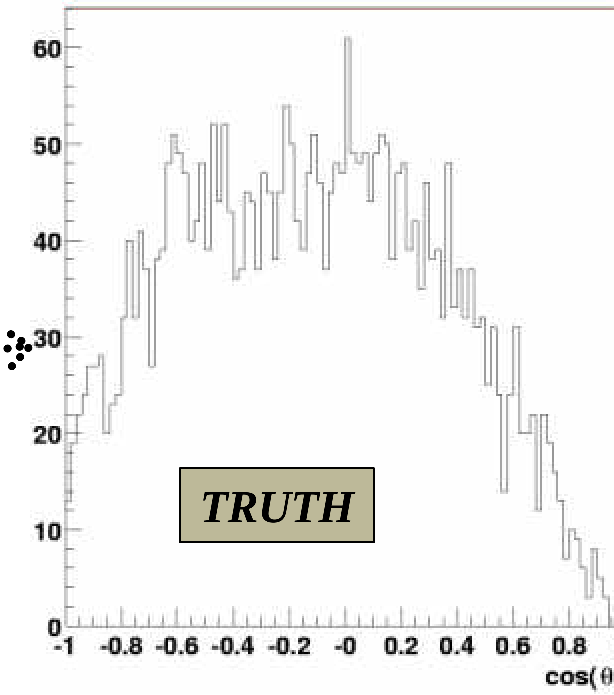
We then re-reconstruct the B_d using this mass cut

Refined cuts

K^{*0} angular distributions



$$\frac{dG(K^{*0} \circledR K^+p^-)}{d\cos(q)} \sim \sin^2(q)$$



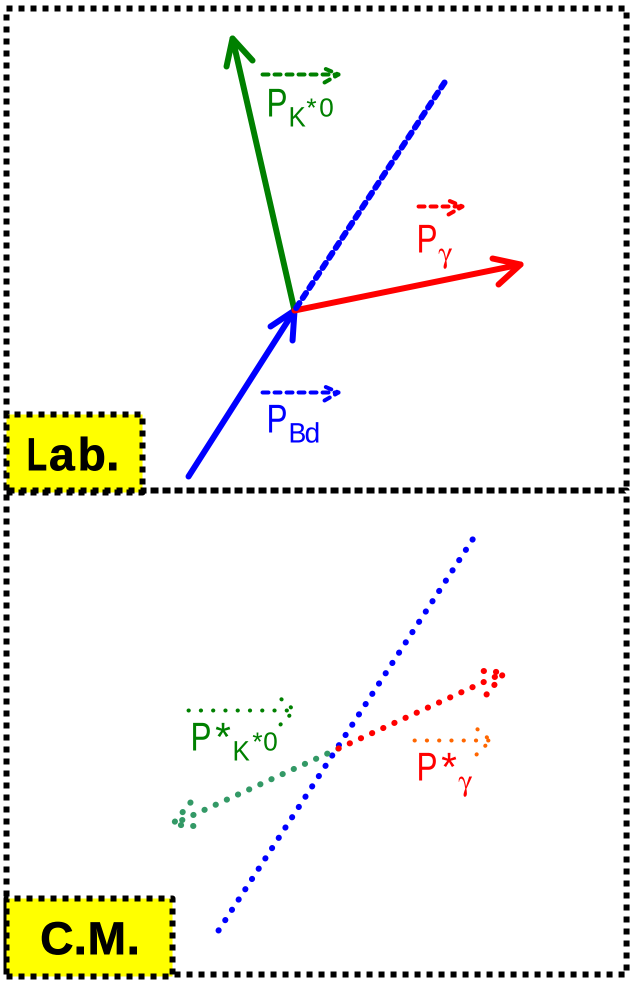
Flat distribution for combinatorial

Interesting cut

Still not used
(Small asymetry should be understood (*vertexing ?*))

Refined cuts

Mass cuts (1/2)



- **In C.M.S. we have :**

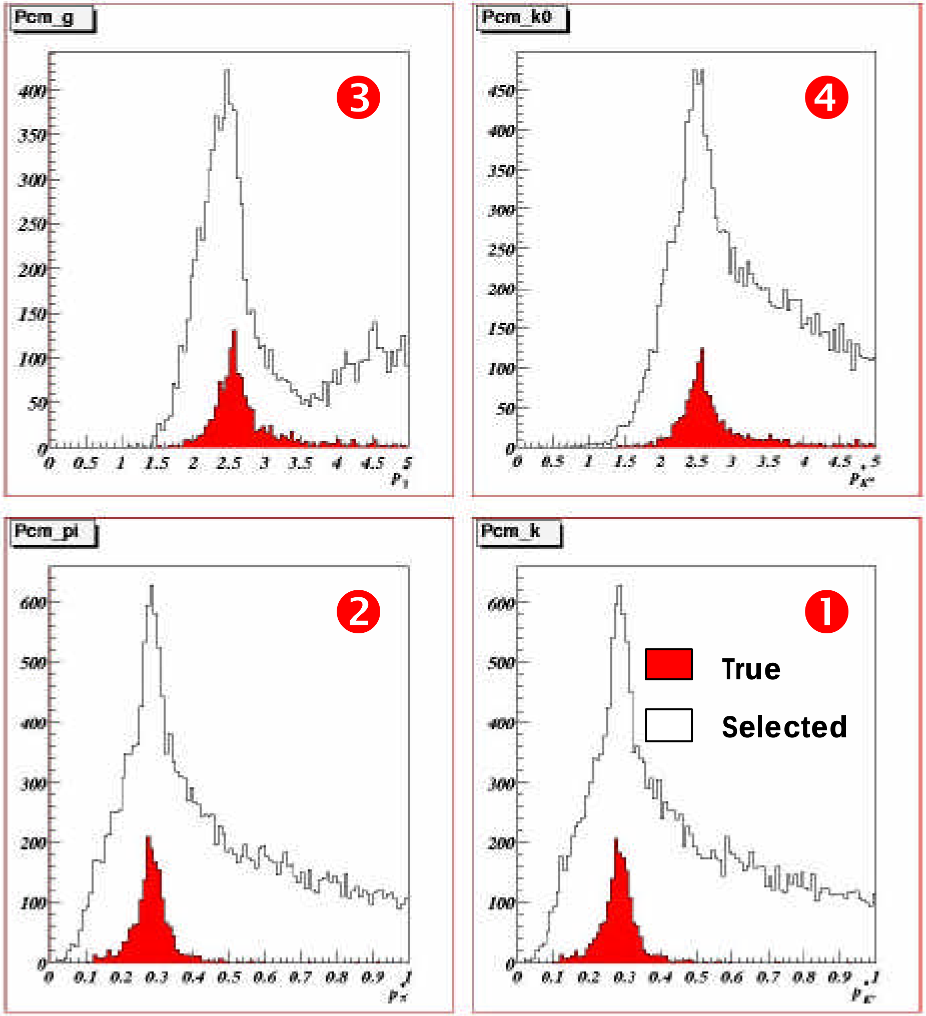
$$\begin{cases} |P^*_{K^{*0}}| = |P^*_g| = 2.56\ \text{GeV} \\ |P^*_{K^+}| = |P^*_{p^-}| = 0.29\ \text{GeV} \end{cases}$$

Cuts on p* ⟷ **Natural mass cuts**

➡ **Use C.M.S. cuts instead of mass windows classic cuts**

Refined cuts

Mass cuts (2/2)



- C.M.S. momenta were calculated.
- K^{*0} is selected if:

❶ $0.2\ GeV < P^*_{K^+} < 0.35\ GeV$

❷ $0.2\ GeV < P^*_{p^-} < 0.35\ GeV$

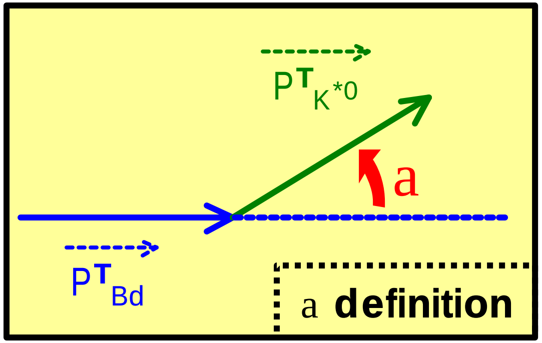
- B_d is selected if:

❸ $1.8\ GeV < P^*_{g} < 3.5\ GeV$

❹ $1.8\ GeV < P^*_{K^{*0}} < 3.5\ GeV$

Refined cuts

K^{*0} transverse direction



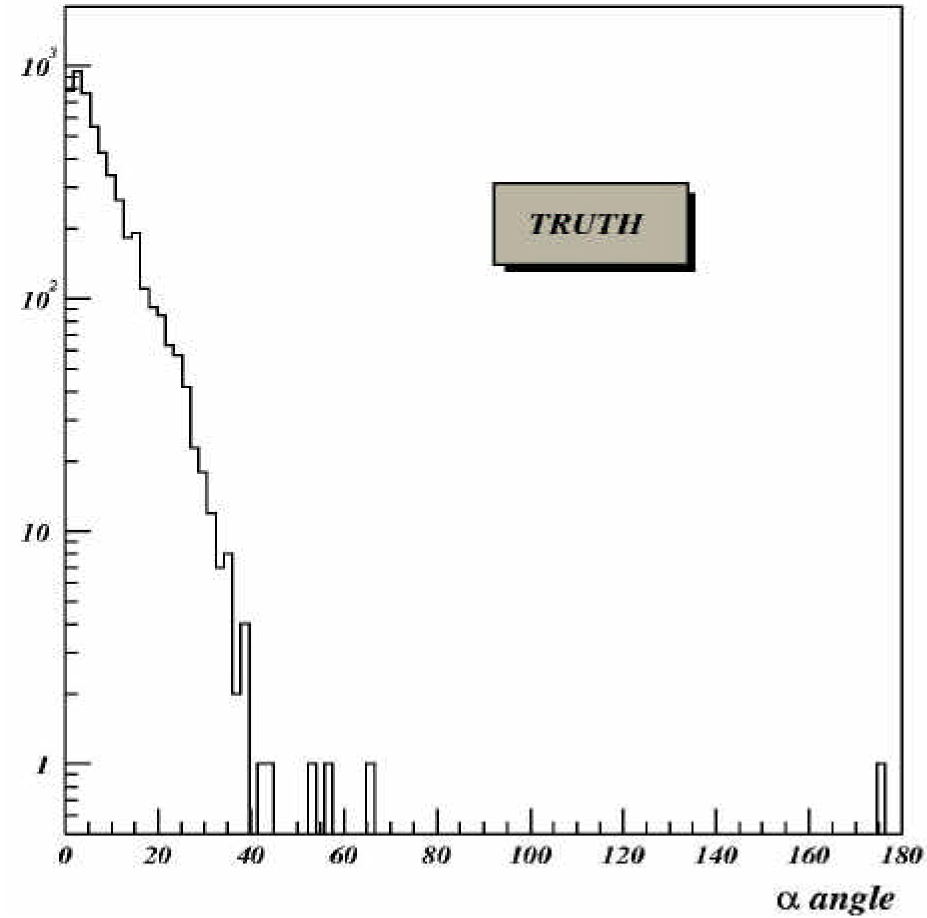
B_d boost

↓

α small

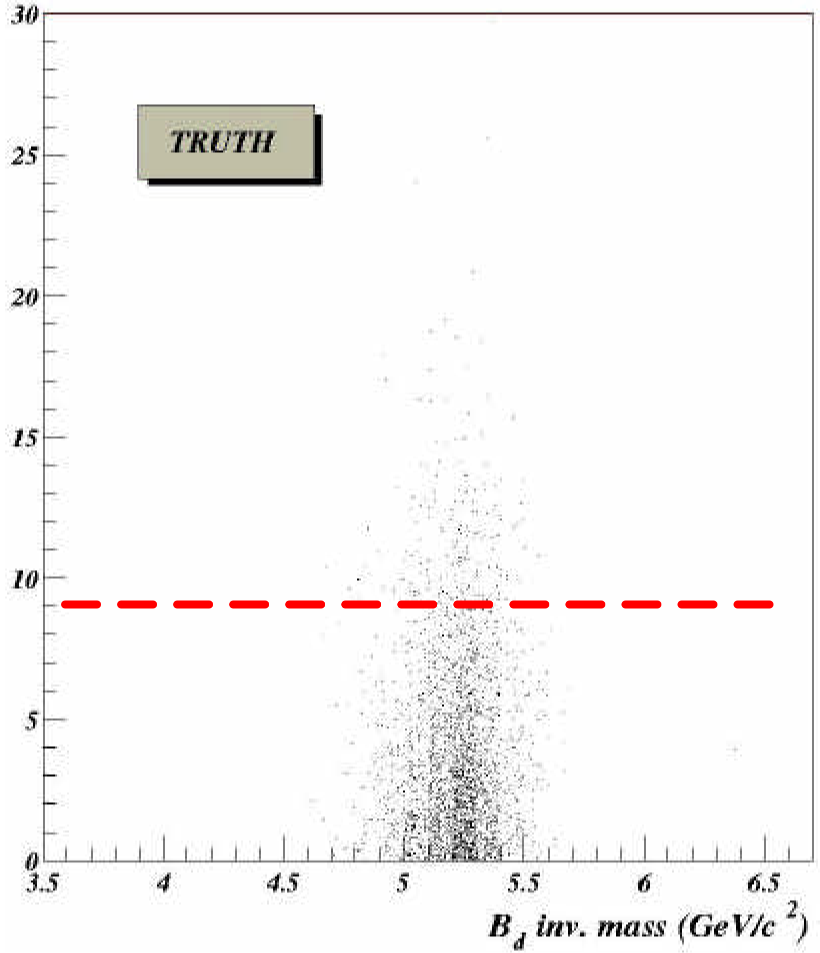
↓

B candidate selected if
a < 40°



Refined cuts

Minimal distance between B_d vertex and γ trajectory



- No information on γ in the ID

➡ **Vertexing routine couldn't be used**

- K^{*0} time of flight very short

➡ **K^{*0} decay vertex = B_d decay vertex**

- γ trajectory should contain this vertex
- Minimal distance between γ trajectory & B-decay vertex is calculated (L_{min}).
- B_d candidate is selected if:

$$\boxed{L_{min} < 9 \text{ cm}}$$

Event rates calculation

Don't forget $\overline{B_d}$ ® $\overline{K^{*0}}$ g !

$$\begin{cases} N_s = 2 \text{ x } \sigma_{prod}(\text{signal}) \text{ x } \varepsilon_{reconstruction}(\text{signal}) \text{ x Br } (B_d \text{ ® } K^{*0}(\text{® K}p) \text{ g }) \text{ x } L_{inst} \\ N_b = \sigma_{prod}(\text{background}) \text{ x } \varepsilon_{reconstruction}(\text{background}) \text{ x } L_{inst} \end{cases}$$

σ_{prod} should be confirmed

s_{prod}(signal) = 0.15 mbarn

(from Pythia)

s_{prod}(background) = 2.89 mbarn

Br (B_d ® K^{*0}(® Kp) g) » 4.44 x 10^{-5}

L_{inst} = $2 \text{x} 10^{33}$ cm^{-2}s^{-1}

N_s = 0.053 e_{reco}(signal)

N_b = 5800 e_{reco}(background)